U. S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

SCIENTIFIC NAME: *Drosophila digressa*

COMMON NAME: No common name

LEAD REGION: Region 1

INFORMATION CURRENT AS OF: April 2010

STATUS/ACTION
___ Species assessment - determined we do not have sufficient information on file to support a proposal to list the species and, therefore, it was not elevated to Candidate status
___ New candidate
_X_ Continuing candidate
___ Non-petitioned
_X_ Petitioned - Date petition received: May 11, 2004
_ 90-day positive - FR date:
X 12-month warranted but precluded - FR date: May 11, 2005
N Did the petition request a reclassification of a listed species?

FOR PETITIONED CANDIDATE SPECIES:
a. Is listing warranted? (if yes, see summary of threats below) Yes
b. To date, has publication of a proposal to list been precluded by other higher priority listing actions? Yes
c. If the answer to a. and b. is "yes", provide an explanation of why the action is precluded.
Higher priority listing actions, including court-approved settlements, court-ordered and statutory deadlines for petition findings and listing determinations, emergency listing determinations, and responses to litigation, continue to preclude the proposed and final listing rules for the species. We continue to monitor populations and will change its status or implement an emergency listing if necessary. The "Progress on Revising the Lists" section of the current CNOR (*http://endangered.fws.gov/*) provides information on listing actions taken during the last 12 months.

_N_ Listing priority change
Former LP: ___
New LP: ___
Date when the species first became a Candidate (as currently defined):
February 28, 1996
___ Candidate removal: Former LPN: ___
___ A – Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.
___U – Taxon not subject to the degree of threats sufficient to warrant issuance of a

proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.

___ F – Range is no longer a U.S. territory.

___ I – Insufficient information exists on biological vulnerability and threats to support listing.

___ M – Taxon mistakenly included in past notice of review.

___ N – Taxon does not meet the Act's definition of "species."

___ X – Taxon believed to be extinct.

ANIMAL/PLANT GROUP AND FAMILY: Insects; Family Drosophilidae (picture-wing fly)

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: Hawaii, island of Hawaii

CURRENT STATES/COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE: Hawaii, island of Hawaii

LAND OWNERSHIP: *Drosophila digressa* is known from five populations, 1 on private land, 3 on State lands, and 1 on Federal land located on the island of Hawaii (Montgomery 1975; Kaneshiro and Kaneshiro 1995; Hawaii Biodiversity and Mapping Program (HBMP) 2006a).

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BIOLOGICAL INFORMATION

Species Description:

Drosophila digressa is a small *Drososphila* picture-wing fly species with adults ranging in size from 0.15 to 0.19 inches (in) (4.0 to 5.0 millimeters (mm)) in length. Adults are essentially brownish yellow in color and have yellow colored legs and hyaline wings (shiny-clear) with prominent brown spots. The wings of *D. digressa* differ from all known Hawaiian *Drosophila* by having a small brown spot at the middle of vein R4+5, but lacking a brown mark in the middle of cell R1 (Hardy and Kaneshiro 1969). This species is similar in structure to other Drosophilidae and other flies in that adults have three main body parts--a head, thorax, and abdomen. One pair of antennae arises from the front of the head, between the eyes. The single pair of wings and three pairs of legs are attached to the thorax. The abdomen is composed of multiple segments. The general life cycle of Hawaiian Drosophilidae is typical of that of most flies: after mating, females lay eggs from which larvae (immature stage) hatch; as larvae grow they molt (shed their skin) through three successive stages (instars); when fully grown the larvae change into pupae (a resting form) in which they metamorphose and emerge as adults (Borror *et al*. 1989).

Taxonomy:
Drosophila digressa was described by Hardy and Kaneshiro (1969), and the species is considered a distinct taxon. Hardy and Kaneshiro (1969) is the most recent and accepted taxonomy for this species.

Habitat/Life History:
Drosophila digressa is restricted to the island of Hawaii. The adult flies are generalist microbivores (microbe eating) and feed upon a variety of decomposing plant material. The eggs are laid within the decomposing bark of native *Charpentiera obovata* trees, where the hatching larvae complete development before dropping to the soil to pupate (Montgomery 1975). *Drosophila digressa* occurs in elevations ranging from 4,200 to 4,600 feet (ft) (1,280 to 1,402 meters (m)) and in mesic to wet forests with rainfall between 79 to 118 in (200 to 300 centimeters (cm)) per year (Montgomery 1975; Kaneshiro and Kaneshiro 1995).

Historical Range/Distribution:
Historically, *Drosophila digressa* was known from five Hawaii Island populations within Moanuiahea Pit Crater (Hualalai), Manuka Forest Reserve (FR), Bird Park (Hawaii Volcanoes National Park), Kipuka 9, and upper Olaa Forest Reserve (aka Pole 44, along Wright Road) (Montgomery 1975; K. Magnacca, University of Hawaii at Hilo, pers. comm. 2006a; 2010; HBMP 2006a). The historical sizes of these populations are unknown, but numbers were never suspected to be large and are believed to have declined.

Current Range/Distribution:
According to Foote and Carson (1995), observations of this species steadily declined during surveys from the period between 1971 and 1993. *Drosophila* researcher, David Foote (U.S. Geological Survey-Biological Resources Discipline, pers. comm. 2009), confirmed that the species has been rarely observed or collected since 2006 despite general (not specific to *D. digressa*) *Drosophila* surveys within its historical habitat. During a year-long period of weekly surveys for the species in Olaa FR site from 1997 to 1998, only five individuals were observed (K. Magnacca, pers. comm. 2006a). Two observations in 2006 confirmed that the species still existed there (K. Magnacca, pers. comm. 2006a), and a recent survey of the area revealed a total of 20 individuals (K. Magnacca, *in litt*., 2010). However, no individuals were observed at the Bird Park site during similarly intensive surveys in 1997 and 1998, and that population may now be extirpated (K. Magnacca, pers. comm. 2006a). The Manuka Forest Reserve site had not been surveyed since 1976 when the species was observed there twice. Adjacent to this area, a substantial population of this species was discovered in August 2009 at Manukā Natural Area Reserve, within the "olopua kipuka" fenced exclosure (19.1179°N, 155.8130°W) (K. Magnacca, *in litt*., 2010). The survey resulted in the observation of 30 individuals, although the presence of large numbers of dead tree ferns in the plant community there suggests that area has been drying out in recent years (K. Magnacca, *in litt*., 2010). The species was observed only once at the Kipuka 9 site, in 1986, despite several surveys prior and afterwards. At the Hualalai site, *D. digressa* was observed once each in 1971 and 1972. The Hualalai site has not been intensively searched since the mid-1970s, but the area is known to have become significantly degraded and it is now unknown whether that population is extant (K. Magnacca, pers. comm. 2006a). To compound the problem, the species' host plant appears to be decreasing throughout its range due

to impacts from browsing ungulates and invasive weed species (Foote and Carson 1995; K. Magnacca, pers. comm. 2006a).

Population Estimates/Status:
No reasonable estimate of current population size or status is currently available; however, the species is presumed to be extant in low numbers at two or more of the five original population sites (D. Foote, pers. comm. 2005; K. Magnacca, pers. comm. 2006a; K. Magnacca, *in litt*., 2010).

THREATS

A. The present or threatened destruction, modification, or curtailment of its habitat or range.
Drosophila digressa's host plant habitat is highly and imminently threatened by feral pigs (*Sus scrofa*), goats (*Capra hircus*), and cattle (*Bos taurus*) that degrade and destroy habitat and eat host plants (Foote and Carson 1995; Kaneshiro and Kaneshiro 1995; Science Panel 2005). Evidence of the activities of feral pigs has been reported at all five *D. digressa* population sites, and the activities of both feral goats and cattle have been reported within the area surrounding the Hulalai population site (Foote and Carson 1995; Kaneshiro and Kaneshiro1995; Science Panel 2005).

Feral Pigs
Pigs of Asian ancestry were introduced to Hawaii by the Polynesians, and the Eurasian type was introduced to Hawaii by Cook in 1778, with many other introductions thereafter (Tomich 1986). Some pigs raised as food escaped into the forests of Hawaii, Kauai, Oahu, Molokai, Maui, and Niihau, formed herds, and are now managed as a game animal by the State to optimize hunting opportunities (Tomich 1986; State of Hawaii 2001). Feral pigs are now found from dry coastal grasslands through rain forests and into the subalpine zone on all of the main Hawaiian Islands (Cuddihy and Stone 1990). Feral pigs create open areas within forest habitat by digging up, eating, and trampling native species (Stone 1985). These open areas become fertile ground for nonnative plant seeds spread through pig excrement and by transport in pig hair (Stone 1985). In nitrogen-poor soils, feral pig excrement increases nutrient availability, enhancing establishment of nonnative weeds that are more adapted to richer soils than native plants (Cuddihy and Stone 1990).

In a study conducted in the 1980s on feral pig populations in the Kipahulu Valley on Maui, the deleterious effects of feral pig rooting on native forest ecosystems was documented (Diong 1982). Rooting by feral pigs was observed to be related to the search for earthworms, with rooting depths averaging 8 in (20 cm), greatly disrupting the leaf litter and topsoil layers, and contributing to erosion and changes in ground topography. The feeding habits of pigs were observed to create seed beds, enabling the establishment and spread of weedy species such as strawberry guava (*Psidium cattleianum*). The study concluded that all aspects of the food habits of pigs are damaging to the structure and function of the Hawaiian forest ecosystem (Diong 1982).

In another study, Foote and Carson (1995), found that pig exclosures on the Big Island supported significantly higher relative frequencies of picture-wing flies compared to other native and

nonnative *Drosophila* species (7 percent of all observations outside of the exclosure and 18 percent of all observations inside the exclosure) and their native host plants. Loope *et al*. (1991) showed that excluding pigs from a montane bog on northeastern Haleakala, Maui, resulted in an increase in native plant cover from 6 to 95 percent after 6 years of protection.

Feral Goats

The goat, a species originally native to the Middle East and India, was successfully introduced to the Hawaiian Islands in 1792. Currently, populations exist on Kauai, Oahu, Maui, Molokai, and Hawaii. Goats browse on introduced grasses and native plants, trample roots and seedlings, cause erosion, and promote the invasion of alien plants. Goats are able to forage in extremely rugged terrain and have a high reproductive capacity (Clarke and Cuddihy 1980; van Riper and van Riper 1982; Scott *et al*. 1986; Tomich 1986; Culliney 1988; Cuddihy and Stone 1990). The effects on mesic and wet forest habitat by foraging of feral goats have also been reported in fencing studies. An exclosure analysis demonstrated that release from goat pressure by fencing resulted in an immediate recovery in height growth and numbers of vegetative resprouts of the native tree *Acacia koa* (koa) (Spatz and Mueller-Dombois 1973). Another study at Puuwaawaa on the island of Hawaii demonstrated that prior to management actions in 1985, regeneration of endemic shrubs and trees in the grazed area was almost totally lacking, contributing to invasion of the forest understory by exotic grasses and weeds. After the removal of grazing animals in 1985, *Acacia koa* and *Metrosideros polymorpha* (ohia) seedlings were observed germinating by the thousands (Department of Land and Natural Resources 2002). Feral goats possibly threaten the Hualalai population of *D. digressa* (Science Panel 2005).

Feral Cattle

Feral cattle occupy a wide variety of habitats from lowland dry forests to montane grasslands, where they consume native vegetation, trample roots and seedlings, accelerate erosion, and promote the invasion of nonnative plants (van Riper and van Riper 1982; Stone 1985; Science Panel 2005). Feral cattle threaten *Drosophila digressa* at the Hualalai population site, where degradation of native forests is evident (Science Panel 2005).

Browsing by feral ungulates, including pigs, goats, and cattle, has been observed on many native plant species, including common and rare or endangered species (Cuddihy and Stone 1990; Loope *et al*. 1991). Because Hawaii's native plants evolved without browsing or grazing pressure, many species lost natural defenses to such impacts (Carlquist 1980, Lamoureux 1994). In the study described above on feral pig populations in the Kipahulu Valley, pigs were observed browsing on young shoots, leaves and fronds of a wide variety plants, of which over 85 percent were endemic species (Diong 1982). A stomach content analysis showed that the pigs' food sources consisted of native plants, 60 percent of which were *Cibotium* spp. (tree ferns), alternating with strawberry guava when it was available. Pigs were observed to fell plants and remove the bark of *Clermontia*, *Cibotium*, *Coprosma*, *Psychotria*, and *Hedyotis* species (herbaceous and woody plants), with larger trees killed over a few months of repeated feeding. Goats often eat nearly all available plants, but their preference is for woody species (Spatz and Mueller-Dombois 1973). *Charpentiera* sp. (papala) (the *Drosophila digressa* host plant) are shrubby trees and are susceptible to browsing by goats. Therefore, even though we have no evidence of direct browsing for *Charpentiera* sp., feral ungulates potentially impact this species.

Hawaiian ecosystems, having evolved without hoofed mammals, are susceptible to large-scale disturbance and grazing by pigs, goats, and other introduced ungulates (Loope *et al*. 1991). Because of demonstrated habitat modifications by feral goats, cattle, and pigs such as destruction of native plants, disruption of topsoil leading to erosion, and establishment and spread of nonnative plants, the Service believes feral goats, cattle, and pigs are threats to *Drosophila digressa*.

Fire

Fire is a potential threat to the habitat and host plants of *Drosophila digressa*, particularly in the mesic portion of its range at the Hualalai population site (Science Panel 2005). Because Hawaiian plants were subjected to fire during their evolution only in areas of volcanic activity, or from occasional lightening strikes, they are not adapted to recurring fire regimes and do not quickly recover following a fire. Alien plants are often better adapted to fire than native plant species, and some fire-adapted grasses have become wide-spread in Hawaii (D'Antonio and Vitousek 1992; Friefelder *et al*. 1998). The presence of such species in Hawaiian ecosystems greatly increases the intensity, extent, and frequency of fire, especially during the drier months or periods of drought. Fire-adapted alien plant taxa can reestablish in a burned area, resulting in a reduction in the amount of native vegetation after a fire. Native shrubland and dry forest can thus be converted to land dominated by nonnative grasses. Habitat damaged or destroyed by fire is more likely to be revegetated by nonnative plants that cannot be used as host plants by picture-wing flies, including *D. digressa* (Kaneshiro and Kaneshiro 1995; Science Panel 2005). Fire can destroy dormant seeds as well as plants, even in steep or inaccessible areas. Fires may result from natural causes, or they may be accidentally or intentionally started by humans (Cuddihy and Stone 1990; D'Antonio and Vitousek 1992; Friefelder et al. 1998).

Nonnative Plants

Drosophila digressa's host plants, *Charpentiera* sp., occur as understory vegetation beneath the canopy of *Metrosideros polymorpha* and *Acacia koa* trees, and are greatly affected by competition with and habitat destruction and degradation by nonnative plant species (Kaneshiro and Kaneshiro 1995; Wagner *et al*. 1999; Science Panel 2005). The most significant of these appear to be lantana (*Lantana camara*), molasses grass (*Melinus minutiflora*), banana poka (*Passiflora tarminiana*), strawberry guava, prickly Florida blackberry (*Rubus argutus*), yellow Himalayan raspberry (*Rubus ellipticus*), and Christmasberry (*Schinus terebinthifolius*) (Smith 1985; Kaneshiro and Kaneshiro 1995; Wagner *et al*. 1999; Science Panel 2005). Jacobi and Warshauer (1992) reported that nonnative plants, including banana poka and strawberry guava, were found in 72 percent of 64 vegetation types sampled in a 1,930 mi^2 (5,000 km^2) study area on the island of Hawaii.

Lantana camara, brought to Hawaii as an ornamental plant, is an aggressive, thicket-forming shrub which is now found on all of the main islands in mesic forest and disturbed habitats (Wagner *et al*. 1999). The most effective control agents are the lace bug *Teleonemia scrupulosa* Stal. (Tingidae); the chrysomelid beetles *Octotoma scabripennis* Guerin-Meneville and *Uroplata girardi* Pic; and the moths, *Hypena strigata* F., *Neogalea sunia* (Guenee) (Noctuidae), and *Salbia haemorrhoidalis* Guenee (Pyralidae). While biological control of lantana by most of the established insects appeared to have reached equilibrium by 1969, the overall impact has been a steady and considerable reduction in abundance of lantana, particularly in drought-prone areas.

Although lantana is considered generally to be under partial to substantial control in drier areas, it still remains a pest in some other environments, such as national parks (Hawaii Department of Agriculture 2006). This species threatens the *Drosophila digressa* Bird Park and Olaa FR populations on Hawaii (Smith 1985; Kaneshiro and Kaneshiro 1995; Science Panel 2005).

Melinus minutiflora is native to Africa, and now introduced to many parts of the tropics as a fodder plant. In Hawaii it is naturalized and common in dry to mesic disturbed open areas on all the main islands except Niihau. It is considered to be a serious pest, choking out and covering native vegetation and preventing seedling establishment (O'Connor 1999). Additionally, this species' dense mats can fuel intense fires and it is able to spread prolifically after a fire, effectively out-competing less fire-adapted native plant species and ultimately creating a stand of nonnative grass where forest once stood (Cuddihy and Stone 1990). Molasses grass threatens the *Drosophila digressa* Hualalai population on Hawaii (Smith 1985; Kaneshiro and Kaneshiro 1995; Science Panel 2005).

Passiflora tarminiana is a vine in the passionflower family. Introduced to the Hawaiian Islands in the 1920s, probably as an ornamental, it is extremely detrimental to certain mesic to wet forest habitats of Kauai, Maui, and Hawaii (Escobar 1999). Heavy growth of this vine can cause damage or death to the native trees by overloading branches, causing breakage, or by forming a dense canopy cover, intercepting sunlight and shading out native plants below (Escobar 1999). This species threatens all five *Drosophila digressa* population sites on Hawaii (Smith 1985; Kaneshiro and Kaneshiro 1995; Science Panel 2005).

Psidium cattleianum is an invasive shrub or small tree native to tropical America, and like *Schinus terebinthifolius*, is capable of forming dense stands that exclude other plant species (Cuddihy and Stone 1990). This nonnative plant grows primarily in mesic and wet habitats and provides food for several nonnative animal species, including feral pigs and game birds, which disperse the plant's seeds through the forest (Smith 1985; Wagner *et al*. 1999; HEAR 2005). To date, no biological control agents have been released against strawberry guava in Hawaii, though insects for biocontrol have undergone host-screening (Institute of Pacific Islands Forestry 2005). Strawberry guava is considered one of the greatest nonnative plant threats to Hawaii's rain forests and is known to pose a direct threat to all five *Drosophila digressa* population sites on the island of Hawaii (Cuddihy and Stone 1990; Jacobi and Warshauer 1992; Wagner *et al*. 1999; Science Panel 2005).

Rubus argutus, a native to the central and eastern United States, was introduced to the Hawaiian Islands in the late 1800s (Wagner *et al*. 1999). The fruit is easily spread by birds to open areas where it can form dense, impenetrable thickets (Smith 1985; Tunison 1991). It is found in mesic to wet forests and subalpine grasslands, ranging from 656 to 7,544 ft (200 to 2,300 m) (HEAR 2005). This species grows via runners underground, and readily resprouts from them if above-ground tissue is treated with herbicide (U.S. Army 2006). Biological controls have been introduced (moths, sawfly, and beetle), but the damage to blackberry so far has been negligible (Nagata and Markin 1986). On Hawaii, all five *Drosophila digressa* population sites are threatened by this species (Kaneshiro and Kaneshiro 1995; Science Panel 2005).

Rubus ellipticus is native to India and widely grown as an ornamental in warm regions. This species has naturalized locally in the Volcano and Laupahoehoe areas of the island of Hawaii. It is a climbing shrub, covered with prickles and edible yellow fruit, and is readily dispersed by birds. This extremely thorny plant forms impenetrable thickets, threatening native ecosystems and the native Hawaiian forest habitat (Benton 2005; Global Invasive Species 2005). Yellow Himalayan raspberry is on the Hawaii noxious weed list and threatens four *Drosophila digressa* population sites on Hawaii (Kaneshiro and Kaneshiro 1995; Science Panel 2005; Hawaii Administrative Rules Title 4, Subtitle 6, Chapter 68).

Schinus terebinthifolius, a shrub native to Brazil, was introduced to Hawaii in 1911 and is now naturalized in mesic areas (Wagner *et al*. 1999). It forms dense thickets and grows even on steep slopes, and the red berries are spread by birds (Smith 1985). Seedlings grow very slowly and can survive in dense shade, exhibiting vigorous growth if the canopy is cleared, leading to the creation of open habitat and further influencing and increasing its rate of spread (Brazilian Pepper Task Force 1997). There are no released biocontrol agents to date (Brazilian Pepper Task Force 1997). Christmasberry is on the Hawaii noxious weed list (Hawaii Administrative Rules 2006) and threatens at least one *Drosophila digressa* population site on Hawaii (Kaneshiro and Kaneshiro 1995; Science Panel 2005).

The original native flora of Hawaii consisted of about 1,400 species, nearly 90 percent of which were endemic. Of the current total native and naturalized Hawaiian flora of 1,817 taxa, 47 percent are introduced species, and nearly 100 species are pests (Smith 1985; Wagner *et al*. 1999a). Confirmed personal observations (HBMP 2006a) and several studies (Cuddihy and Stone 1990; Wood and Perlman 1997; Robichaux *et al*. 1998) indicate nonnative plant species may outcompete native plants similar to *Charpentiera* sp. Competition may be for space, light, water, or nutrients, or there may be a chemical produced that inhibits growth of other plants (Smith 1985; Cuddihy and Stone 1990). In addition, nonnative pest plants found in habitat similar to that of *Charpentiera* sp. have been shown to make the habitat less suitable for native species (Smathers and Gardner 1978; Smith 1985; Loope and Medeiros 1992; Medeiros *et al.* 1992; Ellshoff *et al.* 1995; Meyer and Florence 1996; Medeiros *et al.* 1997; Loope *et al*. 2004). In particular, nonnative pest plant species degrade habitat by modifying availability of light, altering soil-water regimes, modifying nutrient cycling, or altering fire characteristics of native plant communities (Smith 1985; Cuddihy and Stone 1990; Vitousek *et al*. 1997).

Because of demonstrated habitat modification and resource competition by nonnative plant species in habitat similar to the mesic to wet *Metrosideros polymorpha- Acacia koa* forest habitat of the host plants (*Charpentiera* sp.), the Service believes nonnative plant species are a threat to *Drosophila digressa*.

B. Over-utilization for commercial, recreational, scientific, or educational purposes.
None known.

C. Disease or predation.
The geographic isolation of the Hawaiian Islands has restricted the number of original successful colonizing arthropods and resulted in the evolution of a unique fauna. An unusually small number (15 percent) of the known families of insects are represented by native Hawaiian species

(Howarth 1990). Entirely absent are some groups that often dominate continental arthropod faunal groups such as social Hymenoptera (group nesting ants, bees, and wasps). Commercial shipping and air cargo to Hawaii has now resulted in the establishment of over 3,372 species of nonnative insects (Howarth 1990; Howarth *et al*. 1995; Staples and Cowie 2001), with continued establishment of 20 to 30 new species per year (Beardsley 1962, 1979; Staples and Cowie 2001).

In addition to the accidental establishment of nonnative species, nonnative predators and parasites for biological control of pests have been purposefully imported and released by individuals, Republic, Territorial, State, and Federal agencies, since 1865. Between 1890 and 2004, 387 nonnative species were introduced, sometimes with the specific intent of reducing populations of native Hawaiian insects (Funasaki *et al*. 1988; Lai 1988; Staples and Cowie 2001). Nonnative arthropods, whether purposefully introduced or adventive, pose a serious threat to Hawaii's native *Drosophila*, through direct predation and competition for food or space (Howarth and Medeiros 1989; Howarth and Ramsay 1991; Kaneshiro and Kaneshiro 1995; Staples and Cowie 2001).

Due to their large colony sizes and systematic foraging habits, species of social Hymenoptera (ants and some wasps) and parasitic wasps pose the greatest predation threat to the Hawaiian picture-wing flies, including *Drosophila digressa* (Carson 1982; Gambino *et al*. 1987; Foote and Carson 1995; Kaneshiro and Kaneshiro 1995). Several alien ant species have been implicated in the extinction or local loss of many native species, including much of the lowland Hawaiian insect fauna (Howarth and Medeiros 1989). All of the native Hawaiian arthropods, including *Drosophila digressa*, evolved without the predation influence of ants or social wasps, and the arrival of these new groups has been especially devastating (Kaneshiro and Kaneshiro 1995).

Wasps

In 1977, an aggressive race of the western yellow-jacket wasp (*Vespula pensylvanica*) became established in the State of Hawaii, and this species is now particularly abundant between 1,969 and 5,000 ft (600 and 1,524 m) in elevation (Gambino *et al*. 1990; Foote and Carson 1995) on Kauai, Oahu, Molokai, Maui, Lanai, and Hawaii Island (Nishida 1997). Yellow jacket wasps are voracious predators in most ecosystems in which they are found. Compared with typical North American populations, yellow-jackets in Hawaii display a high incidence of colonies that overwinter and persist into at least a second year. The result is that numbers of workers at such colonies are much greater than at annual colonies (Gambino *et al*. 1987). Yellow-jacket colonies in Hawaii can each produce over a half-million foragers that consume tens of millions of arthropods (Gambino and Loope 1992). In Haleakala National Park on Maui, yellow-jackets were found to forage predominantly on native arthropods (Gambino *et al*. 1987, 1990; Gambino and Loope 1992) and have been observed carrying and feeding upon recently captured adult Hawaiian *Drosophila* (Kaneshiro and Kaneshiro 1995). Picture-wing flies, including *D. digressa*, may be particularly vulnerable to predation by wasps due to their lekking behavior, conspicuous courtship displays that can last for several minutes, and relatively large size (K. Kaneshiro, University of Hawaii at Manoa, pers. comm. 2006).

The disappearance of numerous picture-wing flies, including *Drosophila digressa*, from historical observation sites over the past 25 years may be due to a variety of factors. While there is no documentation that conclusively ties this decrease in observations with the establishment of

yellow-jacket wasps within their habitats, the concurrent arrival of wasps and decline of picture-wing fly observations in some areas suggest that the wasps may have played a significant role in the decline of some of the picture-wing fly populations, including that of *D. digressa* (Carson 1982, 1986; Foote and Carson 1995; Kaneshiro and Kaneshiro 1995; Science Panel 2005). Yellow jacket wasps are widespread within the two *D. digressa* population sites near Hawaii Volcanoes National Park (Foote and Carson 1995; Kaneshiro and Kaneshiro 1995; Science Panel 2005).

While some research involving yellow jacket control through the use of poisoned baiting within nearby areas in Hawaii Volcanoes National Park has been conducted periodically in recent years, it is unlikely that any positive carryover effect benefited the species, and ongoing yellow jacket wasp control has not been implemented as any part of a management plan for the geographic areas containing *Drosophila digressa* populations. Furthermore, researchers have unfortunately yet to establish a cost-effective and logistically feasible method of controlling yellow jacket wasps (Foote and Carson 1995; D. Foote, pers. comm. 2005b; Science Panel 2005).

The number of native parasitic Hymenoptera (parasitic wasps) in Hawaii is limited, and only species in the family Eucoiliidae are known to use Hawaiian picture-wing flies as hosts (Kaneshiro and Kaneshiro 1995). However, several species of small parasitic wasps (Family Braconidae), including *Diaschasmimorpha tryoni* (No Common Name (NCN)), *D. longicaudatus* (NCN), *Opius vandenboschi* (NCN), and *Biosteres arisanus* (NCN), were purposefully introduced into Hawaii to control nonnative pest tephritid fruit flies (Funasaki *et al*. 1988). These parasitic wasps are also known to attack other species of flies, including native flies in the family Tephritidae. While these parasitic wasps have not been recorded parasitizing Hawaiian picture-wing flies and may not successfully develop in Drosophilidae, females will sting any fly larva available in their attempts to oviposit (lay eggs) and can cause mortality (T. Duan, University of Hawaii at Manoa, pers. comm. 1995).

Ants

Ants, family Formicidae within the order Hymenoptera, are not a natural component of Hawaii's arthropod fauna, and native species evolved in the absence of predation pressure from ants. Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). These attributes allow some ants to affect prey populations independent of prey density; thus ants can locate and destroy isolated populations and individuals (Nafus 1993a, 1993b). To complicate matters, most ant species have winged reproductive adults (Borror *et al*. 1989) and once established anywhere in the State, they are likely to colonize suitable habitats on all islands in time (Hawaiian Ecosystems at Risk Project (HEAR) 2005).

At least 44 species of ants are known to be established on the Hawaiian Islands (HEAR 2005), and at least 4 particularly aggressive species have severely affected the native insect fauna (Zimmerman 1948; HEAR 2005). Numerous other ant species are recognized as threats to native invertebrates, and additional species become established regularly. While the larvae of most of the Hawaiian picture-wing flies, including *D. digressa*, feed within the substrate of their host plants, they emerge to locate a pupation site in the ground at which time they are exposed to predation by ants. Adult flies emerging from pupation in the ground are also susceptible to

predation, and adult picture-wing flies have been observed with ants attached to their legs (Kaneshiro and Kaneshiro 1995).

Big-headed ants (*Pheidole megacephala*)
With few exceptions, native insects, including many fly species, have been eliminated in habitats where the big-headed ant occurs on the Hawaiian islands of Kauai, Oahu, Maui, Molokai, Lanai, and Hawaii (Perkins 1913; Gagne 1979; Gillespie and Reimer 1993). Although it has only been observed attacking laboratory populations of fruit flies (Wong *et al*. 1984), the big-headed ant is thought to be a threat to picture-wing flies, including *D. digressa*, on the island of Hawaii in the Hualalai population site area (Science Panel 2005).

Argentine ants (*Iridomyrmex humilis*)
The Argentine ant was discovered on the island of Oahu in 1940, and is now established on all the main Hawaiian Islands (Reimer *et al*. 1990). The Argentine ant is found below 2, 950 ft (900 m) in elevation, but is a particular problem for native insect communities at higher elevations ranging up to 7,875 ft (2,400 m) (Reimer *et al*. 1990; Cole *et al*. 1992), where other ant species are not found. This species has been documented to reduce populations, or even eliminate, native arthropods in Haleakala National Park on Maui (Cole *et al*. 1992). Also on Maui, Argentine ants are significant predators on pest fruit flies (Wong *et al*. 1984). Argentine ants do not disperse by flight. Instead colonies are moved about with soil and construction material; a colony was recently discovered on an isolated peak on the island of Oahu under a radio tower. While we are not aware of documented occurrences of predation by Argentine ants on picture-wing flies, including *D. digressa*, they are considered to be a threat to native arthropods located at higher elevations (Cole *et al*. 1992) and thus potentially to *D. digressa* (Science Panel 2005).

Long-legged ants (*Anoplolepis longipes*)
The long-legged ant appeared in Hawaii in 1952, and now occurs on Kauai, Oahu, Maui, and Hawaii (Reimer *et al*. 1990). Direct observations indicate that Hawaiian arthropods are susceptible to predation by this species. Gillespie and Reimer (1993), and Hardy (1979) documented the disappearance of most native insects from Kipahulu Stream on Maui after the area was invaded by the long-legged ant. Although only cursory observations exist, long-legged ants are thought to be a potential threat to *D. digressa* on the island of Hawaii in the Hualalai population site area (Science Panel 2005).

Fire ants (*Solenopsis* sp.)
At least two species of fire ants, *Solenopsis geminata* and *S. papuana*, are also significant threats to native invertebrates (Gillespie and Reimer 1993) and occur on all the main Hawaiian Islands (Reimer *et al*. 1990; Nishida 1997). *Solenopsis geminata* is known to be a significant predator on pest fruit flies in Hawaii (Wong and Wong 1988). Besides the Argentine ant, *Solenopsis papuana* is the only abundant, aggressive ant that has invaded intact mesic forest above 2,000 ft (600 m), and it is expanding its range in the Hawaiian Islands (Reimer 1993).

Based on the findings discussed above, nonnative predatory and parasitic insects are considered significant factors contributing to the reduction in range and abundance of *D. digressa*, and in combination with habitat loss, are a threat to its continued existence (Science Panel 2005). Disease is not known to be a threat to *D. digressa*.

D. The inadequacy of existing regulatory mechanisms

While *Drosophila digressa* has been recorded on federally owned land, none of its *Charpentiera* sp. host plants are listed as threatened or endangered, and therefore this species currently receives no protection under Hawaii's endangered species law (HRS, Sect. 195-D), the Federal Endangered Species Act (16 U.S.C. §1531-1544), or other local laws, treaties, or regulations. Furthermore, as discussed in the Disease and Predation section (above), regulatory mechanisms designed to prevent the introduction and establishment of nonnative insects are inadequate given that over 3,300 species of nonnative insects have become established in Hawaii (Howarth 1990; Howarth *et al*. 1995; Staples and Cowie 2001).

Under Hawaii's Plant Quarantine Law (Hawaii Revised Statues Chapter 150A), the State of Hawaii requires that introductions of biological controls be reviewed by the Board of Agriculture before release. The U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) regulates the importation and release of biological controls through the Plant Protection Act of 2000 (7 USC 7701 et seq.). APHIS requires a risk analysis for each species proposed for release. In order for a species to be approved for releases, the risk analysis must ensure that introduced biological control agents are limited in host range and do not pose a threat to listed species or native plants, or crops. Nevertheless, some nonnative wasp species have been introduced by Federal and State agencies for biological control of pest flies to the possible detriment of picture-wing flies. Because the post-release biology and host range are difficult to predict from laboratory studies done prior to all releases (Gonzalez and Gilstrap 1992; Roderick 1992), the purposeful release or augmentation of any dipteran predator or parasitoid is a potential threat to *D. digressa* (Simberloff 1992; Kaneshiro and Kaneshiro 1995).

Pigs are managed in Hawaii as game animals but many populate inaccessible areas where hunting is difficult, if not impossible, and therefore has little effect on their numbers (Hawaii Heritage Program 1990). Pig hunting is allowed on all islands either year-round or during certain months, depending on the area (Hawaii Department of Land and Natural Resources n.d.-a, n.d.-b, n.d.-c, n.d.-d.); however, public hunting is not adequate to eliminate this threat to the host plants of *Drosophila digressa*.

E. Other natural or manmade factors affecting its continued existence.

The Hawaiian Islands now support several established species of nonnative tipulid flies, and the larvae of some species feed within the decomposing bark of *Charpentiera* sp. (Science Panel 2005; K. Magnacca, pers. comm. 2005; S. Montgomery, Montane Matters/Bishop Museum, pers. comm. 2005a). These tipulid larvae feed within the same portion of the decomposing host plant area normally occupied by the *D. digressa* larvae during their development. The effect of this competition is a reduction in available host plant material for *D. digressa* larvae (Science Panel 2005). In laboratory studies, Grimaldi and Jaenike (1984) demonstrated that competition between *Drosophila* larvae and other fly larvae can exhaust food resources, which affects both the probability of larval survival and the body size of adults, resulting in reduced adult fitness, fecundity, and lifespan.

Hawaiian picture-wing flies, including *Drosophila digressa*, evolved in isolated habitats, resulting in tremendous speciation (Williamson 1981); as a result, small population size may be

less of a threat component than small habitat size (Science Panel 2005). *Drosophila digressa* is now possibly reduced to 5 or fewer populations within localized patches of its host plant species, compounding the effects of numerous other factors causing its decline. This circumstance makes the species more demographically vulnerable to extinction due to a variety of natural processes or random catastrophes such as hurricanes (Lande 1988).

CONSERVATION MEASURES PLANNED OR IMPLEMENTED

No fencing or pig management other than hunting is occurring within 5 of the 6 specific population sites for *Drosophila digressa* (D. Foote, pers. comm. 2005a; 2006). However, a substantial population of this species was discovered in August 2009 at Manukā Natural Area Reserve, within the "olopua kipuka" fenced exclosure (19.1179°N, 155.8130°W), and adjacent to its historical population site in the area (K. Magnacca, *in litt*., 2010). Furthermore, within other areas of Hawaii Volcanoes National Park, fencing and pig control have been implemented, thereby possibly providing some protection to host plants and habitat that may occur there (K. Magnacca, pers. comm. 2006b). In addition, periodic wasp control research has been implemented within certain areas of Hawaii Volcanoes National Park (D. Foote, pers. comm. 2005b).

SUMMARY OF THREATS

Although never abundant, *Drosophila digressa* was originally known from five (now six (K. Magnacca, in litt., 2010)) population sites located within four different, widely separated geographic areas. However, this species has not been recently observed at two of these sites and may now be limited to just two or three sites. Based upon our evaluation of host plant habitat degradation and loss by feral ungulates, fire, and nonnative plants, direct predation by nonnative social insects, and competition at the larval stage with nonnative tipulid flies, we conclude there is sufficient information to develop a proposed rule for *Drosophila digressa*. We find that this species is warranted for listing throughout all its range, and, therefore, find that it is unnecessary to analyze whether it is threatened or endangered in a significant portion of its range.

RECOMMENDED CONSERVATION MEASURES

Demographics will likely be influenced by native forest habitat protection and host plant availability as well as by predatory wasp populations and other insects competing for use of its host plants. Repeat surveys of sites with known historical populations are needed as well as further systematic surveys into nearby localities. Use of remote sensing and data from plant and insect surveys may help to develop models of *D. digressa*'s host plant distribution, which in turn may be used for targeting survey locales. If extant populations are fenced and feral ungulates are removed from the area it is likely that *D. digressa* habitat quality will improve. Control strategies will need to be developed and implemented to manage nonnative plant species and nonnative social insects which may occur in or adjacent to key *D. digressa* habitat. In summary, the experts present at the 2005 science panel stated that the most significant step to recovery for endemic *Drosophila* sp. involves the conservation of the host plant habitat for the species (Science Panel 2005).

- Protect host plant populations from feral ungulates including pigs, goats, and cattle
- Research and implement methods to control nonnative plant species, particularly *Schinus terebinthifolius, Psidium cattleianum, Melinus minutiflora, Lantana camara, Rubus*

argutus, *Passiflora mollissma*, and *Rubus* spp.

- Research and implement control methods, such as poison baiting, for nonnative social insect species
- Conduct field surveys at known locations and in suitable habitat

LISTING PRIORITY

THREAT			
Magnitude	Immediacy	Taxonomy	Priority
High	**Imminent**	Monotypic genus	1
		Species	**2 ***
		Subspecies/population	3
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/population	6
Moderate to Low	Imminent	Monotypic genus	7
		Species	8
		Subspecies/population	9
	Non-imminent	Monotypic genus	10
		Species	11
		Subspecies/population	12

Rationale for listing priority number:

Magnitude:
This species is highly threatened by feral ungulates that degrade and destroy host plant habitat and nonnative plants that degrade habitat and compete with native host plants for light, space, and nutrients. Predation by nonnative social insects is also a serious threat. Threats to the native forest habitat of *Drosophila digressa*, and to individuals of this species, occur throughout its range and are expected to continue or increase without their control or eradication. No known conservation measures have been taken to date to specifically address these threats.

Immediacy of threats:
Threats to *Drosophila digressa* host plant habitat from feral ungulates and nonnative plants and direct predation by nonnative social insects are considered imminent because they are ongoing.

Yes Have you promptly reviewed all of the information received regarding the species for the purpose of determining whether emergency listing is needed?

Is Emergency Listing Warranted? No. The species does not appear to be appropriate for emergency listing at this time because the immediacy of the threats is not so great as to imperil a significant proportion of the taxon within the time frame of the routine listing process. If it

becomes apparent that the routine listing process is not sufficient to prevent large losses that may result in this species' extinction, then the emergency rule process for this species will be initiated. We will continue to monitor the status of the species as new information becomes available. This review will determine if a change in status is warranted, including the need to make prompt use of emergency listing procedures.

DESCRIPTION OF MONITORING

Much of the information in this form is based upon an unpublished manuscript submitted to the Service by Dr. Ken Kaneshiro in 1995 as part of an initial prelisting proposal for 18 species of Hawaiian picture-wing flies. Since 1995, additional information has been contributed by several *Drosophila* researchers from the USGS-BRD, the University of Hawaii, and the University of California at Berkeley.

In 2004, the Pacific Islands Office contacted the following *Drosophila* experts for new status information: Dr. Ken Kaneshiro (University of Hawaii at Manoa); Dr. David Foote (USGS-BRD); and Dr. Steve Montgomery (Montane Matters/Bishop Museum). No new status information was received.

In November 2005, prior to the final comment period for the listing of 12 Hawaiian picture-wing flies (USFWS 2006), the Service convened a panel of three scientists from outside the Service with expertise in Hawaiian *Drosophila* to help synthesize and address uncertainties in the scientific information available for the 12 species, particularly threats to their existence (Science Panel 2005). The purpose of the Science Panel was to assess threats for each of the 12 picture-wing flies, identify and resolve areas of scientific uncertainty, and discuss extinction risks in a carefully structured format. The panelists discussed taxonomy, adaptive radiation of picture-wing flies, hybridization, sexual selection, survey methods, the *Drosophila* lifecycle, and species' distributions (Science Panel 2005). The panel then discussed specific threats to each of the flies and their host plant habitat. While the panel did not address the threats to *Drosophila digressa* specifically, the researchers provided information regarding the current status of threats within the same geographic areas containing this species' populations and host plant habitat. Accordingly, we were able to make several appropriate inferences and update the information contained within this candidate form.

In an effort separate from the 2005 science panel, the Pacific Islands Office contacted the following *Drosophila* experts for new status information: Ms. Betsy Gagne (State of Hawaii NARS Commission); Dr. Neal Evenhuis (Bishop Museum); Mr. David Preston (Bishop Museum); Dr. Ken Kaneshiro (University of Hawaii at Manoa); Dr. David Foote (USGS-BRD); Dr. Patrick O'Grady (University of California at Berkeley); and Dr. Steve Montgomery (Montane Matters/Bishop Museum). No new status information was received.

In 2006, the Pacific Islands Office contacted the following *Drosophila* experts for new status information:

Name	Date	Place of Employment
David Foote	September 6, 2006	USGS- BRD

Ken Kaneshiro	September 6, 2006	University of Hawaii
Karl Magnacca	September 6, 2006	University of California at Berkeley
Steve Montgomery	September 6, 2006	Montane Matters/Bishop Museum

New status information regarding *D. digressa* and several edits to the candidate form were provided by Dr. Magnacca and were incorporated into this current assessment.

This level of monitoring is appropriate to update the status of the species because a thorough literature search was conducted as well as relevant species experts contacted. Information contained in this assessment form was verified by a species expert. The Hawaii Biodiversity and Mapping Program identified this species as critically imperiled (HBMP 2006b). This species is not included in the International Union for Conservation of Nature (IUCN) and Natural Resources Red Data List database (IUCN Natural Resources database 2006); nor is it included in the list of species in Hawaii's 2005 Comprehensive Wildlife Conservation Strategy (Mitchell *et al*. 2005).

In 2008, no new information was provided on this species.

In 2009, Dr. David Foote (USGS-BRD) confirmed that this species has not been seen since 2006.

In 2010, Dr. Karl Magnacca (University of Hawaii at Hilo) confirmed 2009 observations of *Drosophila digressa* at two population sites, including upper Olaa Forest Reserve (aka Pole 44, along Wright Road) (20 individuals), and at the Manukā Natural Area Reserve, within the "olopua kipuka" fenced exclosure (19.1179°N, 155.8130°W) (30 individuals) (K. Magnacca, *in litt*., 2010).

COORDINATION WITH STATES

In January 2010 we provided the Hawaii Division of Forestry and Wildlife with copies of our most recent candidate assessments for their review and comment. No additional information was received from the State.

LITERATURE CITED

Beardsley, J.W. 1962. On accidental immigration and establishment of terrestrial arthropods in Hawaii during recent years. Proc. Hawaii. Entomol. Soc. 18:99-109.

Beardsley, J.W. 1979. New immigrant insects in Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23:35-44.

Benton, N. 2005. Fact sheet: yellow Himalayan raspberry *Rubus ellipticus*. Plant Conservation Alliance's Alien Plant Working Group. 2 pp. http://www.nps.gov/plants/alien, downloaded on December 16, 2006.

Borror, D.J., C.A. Triplehorn and N.F. Johnson. 1989. Introduction to the Study of Insects, Sixth Ed. Saunders College Publishing, Philadelphia.

Brazilian Pepper Task Force. 1997. Brazilian pepper management plan for Florida, Amy Ferriter (ed.), The Florida Exotic Pest Plant Council. 26 pp.

Carlquist, S. 1980. Hawaii: A Natural History, 2nd edition. Pacific Tropical Botanical Garden, Honolulu. 468 pp.

Carson, H.L. 1982. Fluctuations in size of certain *Drosophila* populations in the Olaa Tract Hawaii Volcanoes National Park: *in* Proc. Fourth Conf. in Natural Sciences, Hawaii Volcanoes National Park, p. 40. [abstract]. Cooperative National Park Resources Unit, Department of Botany, Univ. of Hawaii.

Carson, H.L. 1986. *Drosophila* populations in the Olaa Tract, Hawaii Volcanoes National Park, 1971-1986. Pp. 3-9. In: C.W. Smith (ed.). Proceedings of the Sixth Conference in Natural Sciences, Hawaii Volcanoes National Park. Cooperative National Park Resources Studies Unit. University of Hawaii. Honolulu, Hawaii.

Clarke, G. and L.W. Cuddihy. 1980. A botanical reconnaissance of the Na Pali coast trail: Kee Beach to Kalalau Valley (April 9-11, 1980). Division of Forestry and Wildlife, Department of Land and Natural Resources, Hilo. Pp. C-10—C-20.

Cole, F.R., A.C. Medeiros, L.L. Loope, and W.W. Zuehlke. 1992. Effects of the Argentine ant on arthropod fauna of Hawaiian high-elevation shrubland. Ecology 73:1313-1322.

Cuddihy, L.W. and C.P. Stone. 1990. Alteration of the native Hawaiian vegetation; effects of humans, their activities and introductions. Coop. Natl. Park Resources Stud. Unit, Hawaii.

Culliney, J.L. 1988. Islands in a far sea: nature and man in Hawaii. Sierra Club Books, San Francisco. 410 pp.

Department of Land and Natural Resources. 2002. Draft management plan for the ahupuaa of Puuwaawaa and the makai lands of Puuanahulu. State of Hawaii, Division of Forestry and Wildlife. p. 52.

Diong, C.H. 1982. Population biology and management of the feral pig (*Sus scrofa* L.) in Kipahulu Valley, Maui. Dissertation to the Zoology graduate division of the University of Hawaii. 408 pp.

D'Antonio, C.M. and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle and global change. Annual Review of Ecology and Systematics 23: 63-88.

Ellshoff, Z.E., D.E. Gardner, C. Wikler, and C.W. Smith. 1995. Annotated bibliography of the genus *Psidium*, with emphasis on *P. cattleianum* (strawberry guava) and *P. guava* (common guava), forest weeds in Hawaii. Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu. Technical Report 95. 105 pp.

Escobar, L.K. 1999. Passifloraceae: *in* Wagner, W.L., D.H. Herbst, S.H. Sohmer (eds), Manual of the Flowering Plants of Hawaii, University of Hawaii Press and Bishop Museum Press, Bishop Museum Special Publication 97. Pp.1,010-1,011.

Foote, D. and H.L. Carson. 1995. *Drosophila* as monitors of change in Hawaiian ecosystems: *in* E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, (Eds.), Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of Interior, National Biological Service, Washington D.C.

Funasaki, G.Y., P.L. Lai, L.M. Nakahara, J.W. Beardsley & A.K. Ota. 1988. A review of biological control introductions in Hawaii: 1890 to 1985. Proc. Hawaii. Entomol. Soc. 28:105-160.

Friefelder, R.R., P.M. Vitousek, and C.M. D'Antonio. 1998. Microclimate change and effect on fire following forest-grass conversion in seasonally dry tropical woodland. Biotropica 30: 286-297.

Gagne, W.C. 1979. Canopy-associated arthropods in *Acacia koa* and *Metrosideros* tree communities along an altitudinal transect on Hawaii Island. Pac. Insects 21:56-82.

Gambino, P., A.C. Medeiros, and L.L. Loope. 1987. Introduced vespids *Paravespula pensylvanica* prey on Maui's endemic arthropod fauna. J. Trop. Ecol. Vol. 3:169-170.

Gambino, P., A.C. Medeiros, and L.L. Loope. 1990. Invasion and colonization of upper elevations on East Maui (Hawaii) by *Paravespula pennsylvanica* (Hymenoptera: Vespidae). Annals of the Entomological Society of America 83**:**1088-1095.

Gambino, P. and L.L. Loope. 1992. Yellowjacket *Vespula pensylvanica* biology and abatement in the National Parks of Hawaii. Cooperative National Park Resources Studies Unit, Hawaii, Technical Report 86**:**1-41.

Gillespie, R.G. and N. Reimer. 1993. The effect of nonnative predatory ants Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae: Tetragnathidae). Pacific Science 47:21-33.

Global Invasive Species Database. 2005. *Rubus ellipticus*. http://www.issg.org/database/species/ecology.asp?si=79&fr=1&sts=sss, downloaded on December 16, 2006.

Gonzalez, D. and F.E. Gilstrap. 1992. Foreign exploration: Assessing and prioritizing natural enemies and consequences of preintroduction studies, pp. 53-70: *in* W.C. Kauffman and J.R. Nichols (Eds.), Selection criteria and ecological consequences of importing natural enemies. Thomas Say Publications in Entomology. Entomological Society of America.

Grimaldi, D. and J. Jaenike. 1984. Competition in natural populations of mycophagous *Drosophila*. Ecology 65: 1113-1120.

Hardy, D.E. 1979. An ecological survey of Puaaluu Stream. Part III. Report on a preliminary entomological survey of Puaaluu Stream, Maui. Coop. Nat. Park Resources Study Unit. University of Hawaii. Tech. Report 27:34-39.

Hardy, D.E. and K.Y. Kaneshiro. 1969. Descriptions of new Hawaiian Drosophila. University of Texas Publications. 6918:39-54.

Hawaii Biodiversity and Mapping Program. 2006a. Program database. Unpublished.

Hawaii Biodiversity and Mapping Program. 2006b. http://www.hinhp.org, downloaded on March 1, 2007.

Hawaii Department of Agriculture. 2006. *Lantana camara*. http://www.hawaiiag.org/hdoa/pi_ppc_bioprob.htm, downloaded on March 12, 2007.

Hawaii, Department of Land and Natural Resources. 1985. Hunting in Hawaii, fourth revision.

Hawaii, Department of Land and Natural Resources. N.d.-a. Summary of Title 13, Chapter 123, Game mammal hunting rules, island of Oahu. Division of Forestry and Wildlife, Honolulu. 2 pp.

Hawaii, Department of Land and Natural Resources. N.d.-b. Summary of Title 13, Chapter 123, Game mammal hunting rules, island of Molokai. Division of Forestry and Wildlife, Honolulu. 2 pp.

Hawaii, Department of Land and Natural Resources. N.d.-c. Summary of Title 13, Chapter 123, Game mammal hunting rules, island of Maui. Division of Forestry and Wildlife, Honolulu. 2 pp.

Hawaii, Department of Land and Natural Resources. N.d.-d. Summary of Title 13, Chapter 123, Game mammal hunting rules, island of Kauai. Division of Forestry and Wildlife, Honolulu. 6 pp.

Hawaiian Ecosystems at Risk Project (HEAR). 2005. http://www.hear.org/ , downloaded on April 19, 2005.

Hawaii Heritage Program. 1990 Management Recommendations for Na Pali coast state park, island of Kauai. The Nature Conservancy, prepared for the Hawaii Department of Land and Natural Resources, Division of State Parks, Honolulu. 18 pp.

Hawaii State Department of Agriculture (HDOA). 1994. Overview of requirements for importation of biological control agents. December 16, 1994. 16pp.

Hawaii State Division of Forestry and Wildlife. 1995. Hawaii Revised Statutes. Section 195D-4. State of Hawaii. Pp. 34.

Howarth, F.G. 1990. Hawaiian terrestrial arthropods: An overview. Bishop Mus. Occas. Pap. 30:4-26.

Howarth, F.G. and A.C. Medeiros. 1989. Nonnative invertebrates: *in* Stone, C.P. and D.B. Stone (Eds.), Conservation Biology in Hawaii. Univ. Hawaii Coop. Natl. Park Resource. Stud. Unit, Honolulu. Pp. 82-87.

Howarth, F.G. and G.W. Ramsay. 1991. The conservation of island insects and their habitats: *in* Collins, N.M. and J.A. Thomas (Eds.), The Conservation of Insects and Their Habitats, Academic Press, London. pp. 71-107

Howarth, F.G., G. Nishida, and A. Asquith. 1995. Insects of Hawaii: Status and Trends: *in* E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, (Eds.), Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Department of Interior, National Biological Service, Washington D.C.

International Union for Conservation of Nature. 2006. 2006 Red List of Threatened Species, http://www.iucn.redlist.org, downloaded on December 18, 2006

Institute of Pacific Islands Forestry. 2005. *Tectococcus ovatus*. A biological control agent proposed for release against strawberry guava (waiawi), research update. Pacific Southwest Research Station, United States Department of Agriculture, Forest Service. 2 pp.

Jacobi, J.D. and F.R. Warshauer. 1992. Distribution of six alien plant species in upland habitats on the island of Hawaii: *in* Alien Plant Invasions in Native Ecosystems of Hawaii. C.P. Stone, C. W. Smith, and J.T. Tunison (Eds.), University of Hawaii Cooperative Natl. Park Resources Studies Unit, Honolulu, University of Hawaii Press. Pp 155-188.

Kaneshiro, K.Y. and K. Kaneshiro. 1995. Draft listing proposal for 18 species of Hawaiian picture-wing *Drosophila*. Document submitted to the Pacific Islands Office, U.S. Fish and Wildlife Service, Honolulu, Hawaii.

Lai, P.Y. 1988. Biological control: A positive point of view. Proc. Hawaii. Entomol. Soc. 28:179-190.

Lamoureux, C.H. 1994. Conserving Hawaiian biodiversity – the role of Hawaiian botanicalgardens. Pp. 55-57, *in* C.-I Peng and C.H. Chou (eds.), Biodiversity and Terrestrial Ecosystems, Institute of Botany, Academia Sinica Monograph Series No. 14.

Lande, R. 1988. Demographic models of the northern spotted owl (*Strix occidentalis caurina*). Oecologia 75: 601-607.

Loope, L., F. Starr, and K. Starr. 2004. Protecting endangered Hawaiian plant species from displacement by invasive plants on Maui, Hawaii. Weed Technology 18: 1472-1474.

Loope, L.L. and A.C. Medeiros. 1992. A new and invasive grass on Maui. Newsletter of the Hawaiian Botanical Society 31: 7-8.

Loope, L., A.C. Medeiros, and B.H. Gagne. 1991. Recovery of vegetation of a montane bog following protection from feral pig rooting. Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu. Technical Report 77. 23 pp.

Medeiros, A.C., L.L. Loope, T. Flynn, S.J. Anderson, L.W. Cuddihy, K.A. Wilson. 1992. Notes on the status of an invasive Australian tree fern (*Cyathea cooperi*) in Hawaiian rain forests. American Fern Journal 82: 27-33.

Medeiros, A.C., L.L. Loope, P. Conant, S. McElvaney. 1997. Status, ecology, and management of the invasive plant, *Miconia calvescens* DC (Melastomataceae) in the Hawaiian Islands. Records of the Hawaii Biological Survey for 1996. Bishop Museum Occasional Papers 48: 23-36.

Meyer, J.Y. and J. Florence. 1996. Tahiti's native flora endangered by the invasion of *Miconia calvescens* D.C. (Melastomataceae). Journal of Biogeography 23: 775-781.

Mitchell, C., C. Ogura, D.W. Meadows, A. Kane, L. Strommer, S. Fretz, D. Leonard, and A. McClung. 2005. Hawaii's comprehensive wildlife conservation strategy. Department of Land and Natural Resources, Honolulu, Hawaii. 722 pp.

Montgomery, S. L. 1975. Comparative breeding site ecology and the adaptive radiation of picture-winged *Drosophila* (Diptera: Drosophilidae) in Hawaii. Proceedings of the Hawaiian Entomological Society. 22:65-103.

Nafus, D.M. 1993a. Biological control agents and native parasitoids in the population system of the butterfly *Hypolimnas bolinas* (L.) (Lepidoptera: Nymphalidae). Micronesica, Suppl. 4:17-23.

Nafus, D. M. 1993b. Extinction, biological control, and insect conservation on islands. Pp. 139-154: In: Gaston, K. J., TR. New, and M. J. Samways (eds.) Perspectives on Insect Conservation. Intercept Ltd., Andover, UK.

Nagata, R.F. and G.P. Markin. 1986. Status of insects introduced in Hawaii for the biological control of the wild blackberry *Rubus argutus*. Proceedings of the Sixth Conference in Natural Sciences, Hawaii Volcanoes National Park, Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu. Pp. 53-64.

Nishida, G.M. (ed.). 1997. Hawaiian Terrestrial Arthropod Checklist. Third ed. Bishop Museum Technical Report No. 12. 263 pgs.

O'Connor, P.J. 1999. Poaceae, grass family: *in* Wagner, W.L., D.R. Herbst, and S.H. Sohmer (eds.), Manual of the Flowering Plants of Hawaii, University of Hawaii Press and Bishop Museum Press, Honolulu, Bishop Museum Special Publications 97. Pp. 1,481-1,604.

Perkins, R.C.L. 1913. Introduction to Fauna Hawaiiensis. D. Sharp, (Ed.), Vol. 1:xv-ccxxvii. Cambridge University Press, Cambridge.

Reimer, N.J. 1993. Distribution and impact of nonnative ants in vulnerable Hawaiian ecosystems: *in* D.F.Williams (Ed.). Exotic Ants: Biology, Impact, and Control of Introduced Species. Westview Press, Boulder, Colorado. Pp. 11-22.

Reimer, N., J.W. Beardsley and G. Jahn. 1990. Pest ants in Hawaii: *in* Vander Meer, R.K, K. Jaffe and A. Cedeno (Eds.). Applied Myrmecology: A World Perspective. Westview Press, Boulder, Colorado. Pp. 40-50.

Robichaux, R., J. Canfield, F. Warshauer, L. Perry, M. Bruegmann, and G. Carr. 1998. "Radiating" plants-adaptive radiation. Endangered Species Bulletin November/December. 3 pp.

Roderick, G. 1992. Post-colonization evolution of natural enemies: *in* W.C. Kauffman and J.R. Nichols (Eds.). Selection criteria and ecological consequences of importing natural enemies. Thomas Say Publications in Entomology. Entomological Society of America.

Science Panel for 12 Species of Hawaiian Picture-wing Flies. 2005. Notes for science panel hosted by the Pacific Islands Fish and Wildlife Office, November 15 to 16, 2005. 23pp.

Scott, J.M., S. Mountainspring, F.L. Ramsey, and C.B. Kepler. 1986. Forest bird communities of the Hawaiian Islands: Their dynamics, ecology, and conservation. Studies in Avian Biology 9: 1-431.

Simberloff, D. 1992. Conservation of pristine habitats and unintended effects of biological control: *in* W.C. Kauffman and J.E. Nechols (Eds.). Selection Criteria and Ecological Consequences of Importing Natural Enemies. Thomas Say Publications in Entomology: Proceedings. Entomological Society of America, Lanham, Maryland. Pp. 105-117.

Smathers, G.A. and D.E. Gardner. 1978. Stand analysis of an invading firetree (*Myrica faya* Aiton) population, Hawaii. Proceedings of the Second Conference on Natural Science, Hawaii Volcanoes National Park. Pp. 274-288.

Smith, C.W. 1985. Impact of nonnative plants on Hawaii's native biota: *in* Stone, C.P., and J.M. Scott (Eds.). Hawaii's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu. Pp. 180-250.

Spatz, Gunter and Dieter Mueller-Dombois. 1973. The influence of feral goats on koa tree reproduction in Hawaii Volcanoes National Park. Ecology 54: 870-876.

Staples, G. W. and R. H. Cowie (Eds.) 2001. Hawaii's Invasive Species. Mutual Publishing and Bishop Museum Press. Honolulu, HI. 111p.

State of Hawaii. 2001. Game mammal hunting guide. http://www.state.hi.us/dlnr/dcre/mammalguide.html, downloaded February 13, 2007.

Stone, C.P. 1985. Nonnative animals in Hawaii's native ecosystems: toward controlling the adverse effects of introduced vertebrates: *in* Stone, C.P., and J.M. Scott (Eds.). Hawaii's terrestrial ecosystems: preservation and management. Coop. Natl. Park Resources Stud. Unit, Univ. Hawaii, Honolulu. Pp. 251-297.

Tomich, P.Q. 1986. Mammals in Hawaii: A Synopsis and Notational Bibliography. 2nd ed. Bishop Museum Press. Honolulu, Hawaii. 375 pp.

Tunison, T. 1991. The Nature Conservancy element stewardship abstract for *Rubus argutus*. The Nature Conservancy, Arlington. 7 pp.

U.S. Army. 2006. MIP weed management: *Rubus argutus*: *in* 2006 status reports for the Makua implementation plan and the draft Oahu implementation plan, Directorate of Public Works, Environmental Division, Schofield Barracks. Pp. 2-1-21 to 2-1-23.

U.S. Fish and Wildlife Service. 2006. Endangered and Threatened Wildlife and Plants; Determination of Status for 12 Species of Picture-wing Flies from the Hawaiian Islands. Federal Register 71(89): 26835.

van Riper, S.G., and C. van Riper III. 1982. A field guide to the mammals in Hawaii. The Oriental Publishing Company, Honolulu. 68 pp.

Vitousek, P.M., C.M. D'Antonio, L.L. Loope, M. Rejmanek, and R. Westerbrooks. 1997. Introduced species: a significant component of human-caused global change. New Zealand Journal of Ecology 21: 1-16.

Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1999. Manual of the flowering plants of Hawaii. Univ. of Hawaii press and Bishop Museum Press, Honolulu. Bishop Mus. Spec. Public. 83: 1-1,853.

Williamson, M. 1981. Hawaiian Drosophilidae: *in* Island populations. Oxford University Press.

Wong, T. T., D. O. McInnis, J. I. Nishimoto, A. K. Ota, and V. C. S. Chang. 1984. Predation of the Mediterranean fruit fly (Diptera: Tephritidae) by the Argentine ant (Hymenoptera: Formicidae) in Hawaii. J. Econ. Entomol. 77: 1454-1458.

Wong, M.A. and T.T.Y. Wong. 1988. Predation of the Mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae) by the fire ant (Hymenoptera: Formicidae) in Hawaii. Proc. Hawaii. Entomol. Soc. 28:169-177.

Wood, K.R. and S. Perlman. 1997. Maui 14 plant survey final report. National Tropical Botanical Garden. 25 pp.

Zimmerman, E.C. 1948. Insects of Hawaii. Vol.1. Introduction. xvii+206 pp. University of Hawaii Press.

Personal Communications

Duan, T. 1995. Personal communication. Conversation between T. Duan, University of Hawaii, and Adam Asquith, (formerly with) U.S. Fish and Wildlife Service, regarding the non-target effects of parasitoid flies, August 14, 1995.

Foote, D. 2005a. Personal communication. Meeting and conversation between David Foote, USGS-BRD, Hawaii Volcanoes National Park, and Mike Richardson, U.S. Fish and Wildlife Service, regarding the status of *Drosophila digressa,* June 23, 2005.

Foote, D. 2005b. Personal communication. Email message from David Foote, USGS-BRD, Hawaii Volcanoes National Park, to Mike Richardson, U.S. Fish and Wildlife Service, regarding yellow jacket studies in and around Hawaii Volcanoes National Park, March 15, 2005.

Foote, D. 2006. Personal communication. Email message from David Foote, USGS-BRD, Hawaii Volcanoes National Park, to Mike Richardson, U.S. Fish and Wildlife Service, regarding fencing and pig management in and around Hawaii Volcanoes National Park including the Olaa Forest Reserve, February 2, 2006.

Foote, D. 2009. Personal communication. Email message from David Foote, USGS-BRD, Hawaii Volcanoes National Park, to Mike Richardson, U.S. Fish and Wildlife Service, regarding the absence of positive observations and collections of *D. digressa* since 2006, April 29, 2009.

Kaneshiro, K. Y. 2006. Personal communication. Email message from Ken Kaneshiro, University of Hawaii at Manoa to Mike Richardson, U.S. Fish and Wildlife Service, regarding the vulnerability of *Drosophila* sp. to social insects including yellow jacket wasps, March 10, 2006.

Magnacca, K. 2005. Personal communication. Email message from Karl Magnacca, University of California at Berkeley to Mike Richardson, U.S. Fish and Wildlife Service, regarding tipulid fly competition in host plants of picture-wing fly species, December 7, 2005.

Magnacca, K. 2006a. Personal communication. Email message from Karl Magnacca, University of California at Berkeley to Mike Richardson, U.S. Fish and Wildlife Service, regarding the status of *Drosophila digressa*, September 9, 2006.

Magnacca, K. 2006b. Personal communication. Email message from Karl Magnacca, University of California at Berkeley to Mike Richardson, U.S. Fish and Wildlife Service, regarding management activities within and adjacent to the Hawaii Volcanoes National Park on the Big Island, February 3, 2006.

Magnacca, K. 2010. Written report from Karl Magnacca, University of Hawaii at Hilo to Mike Richardson, U.S. Fish and Wildlife Service, regarding observations at two population sites in 2009.

Montgomery, S. 2005a. Personal communication. Email message from Steve Montgomery, Montane Matters/Bishop Museum to Mike Richardson, U.S. Fish and Wildlife Service regarding the *Drosophila* host plant genera affected by tipulid flies, December 7, 2005.

Montgomery, S. 2005b. Personal communication. Email message from Steve Montgomery, Montane Matters/Bishop Museum to Mike Richardson, U.S. Fish and Wildlife Service regarding *Drosophila* host plant genera affected by rat and feral ungulate predation, December 15, 2005.

APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve:

Acting Carolyn A. Bohan
Regional Director, Region 1, Fish and Wildlife Service 5/18/10 Date

Lowell W Hovell
ACTING
Director, Fish and Wildlife Service October 22, 2010

Concur:

Do not concur: _____
Director, Fish and Wildlife Service Date

Director's Remarks:

Date of annual review:
Conducted by: Mike Richardson, Pacific Islands FWO Date: April 8, 20010
Biologist, Prelisting and Listing Program

Comments:

PIFWO Review

Reviewed by: Christa Russell Date: April 22, 2010
Prelisting and Listing Program Coordinator

Marilet Zablan Date: April 26, 2010
Assistant Field Supervisor, Endangered Species

Gina Shultz Date: April 30, 2010
Acting Field Supervisor